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METHODS FOR INVESTIGATING THE EFFECT OF DRUGS ON PSYCHOLOGICAL FUNCTION[1]

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and

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In ancient times, the use of drugs was shrouded in such superstition, mysticism, and ignorance that a patient's survival appears now in the nature of a miracle. The function of the human body was a mystery to early physicians. Although many drugs which are still valuable, such as digitalis, were used in the early nineteenth century, their mode of action was not understood. It sufficed the early physician to know that the patient's symptoms were yielding to the treatment, however empirical. He did not aspire to understand the manner in which the drug acted on the body.

In the past century medicine has made rapid progress in its knowledge of human physiology. Biochemistry and pharmacology have made available a vast number of new substances for the treatment of disease. The attitude toward pharmacological action during this time has been typical of the early medical attitude toward the patient, i.e., a preoccupation with the disease under treatment rather than with the patient as a whole personality. This tendency to concentrate attention on the disease rather than on patient has meant, until recently, that the effect of a drug was studied in relation to the way in which medication relieved specific symptoms instead of the entire human organism.

The basic attitude toward pathology has undergone a profound alteration. There is a greater tendency to treat the "patient as a person." In line with this approach has come a change in the manner in which various therapies are evaluated. The investigation of the action of drugs has been greatly affected by this new point of view. In the past, drugs were studied only by physiological and chemical techniques supplemented occasionally by clinical studies. The so-

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called "psychological approach" to the study of drug action is a relatively recent method.

In the psychological study of drugs, the investigator is not chiefly concerned with the action of drugs in a strict medical sense, although he may note these manifestations. Primarily, he is concerned with the way in which a given drug affects the entire personality of the subject or the individual under treatment. The investigator asks, "How does this drug affect the higher mental processes? Does it alter the patient's personality, making him moody, slow, stupid, unresponsive, or unduly excited? Does the patient regress mentally?" The psychologist is interested in evaluating drug treatment in terms of the effect on the patient as a whole and he may conclude that the use of a certain drug is not warranted although it relieves some physical symptoms. When medication is followed by undesirable mental changes or personality disturbances, the results may be more undesirable than the symptoms which indicated the use of the drug.

Many drugs have been re-evaluated by psychological methods in recent years. Among them are acetanilid, alcohol, benzedrine, bromide, caffeine, curare, cocaine, ephedrine, marijuana, morphine, nicotine, opium, sodium amytal and strychnine. Alcohol, benzedrine and caffeine have received attention in a large number of investigations.

As long ago as 1896, Loewald (1) published a paper under the sponsorship of Kraepelin dealing with the psychic effects of bromide salts. Modern interest in bromide preparations is based upon the practical observation that the drug constitutes about one-seventh of the medical prescriptions of drugs for internal use (2). In addition to its widespread use by physicians, either alone or in combination with other drugs, bromide preparations are available without prescription to the general public, under various proprietary names, and in combination with various other ingredients (3).

Animals have been favorite subjects for most experiments, since there remains a popular prejudice against human "guinea pigs." Moreover, it is possible to minimize the factor of subjective disturbance in animal subjects which always operates when hospital patients are used. The possibility of rigid control in animal experiments is an additional advantage although they are always subject to the criticism that the results may not be comparable with those obtainable from human subjects.

A typical psychological study of drug action on human subjects was undertaken by Hollingworth (4), using caffeine. He used motor tests to see how the drug affected steadiness and muscular coordination, and also investigated its influence on perception, association, discrimination, attention, and judgment. In working with strychnine, Poffenberger (5) used motor tests and also tested his subjects on color-naming, cancellation, addition and multiplication. Reifenstein and Davidoff (6) have carried out an exceedingly extensive and thorough study of benzedrine sulfate, using continuous addition, the Witmer form board, the reproduction of card designs, the Rorschach test, and others. All these studies have a common approach in that they attempt to describe the effects of a given drug in terms of how it disturbs or alters such psychological functions in man as may be measured by tests of memory, association, reasoning, or discriminatory ability.

The tests which are chosen for the experimental study of a drug will be affected in some measure by the known characteristic action of the drug. The speed of the drug's action, whether cumulative or not, and the duration of its action will determine the composition of the test battery to some extent. If the investigation must cover a prolonged period, the possibility that test scores might be improved by practice or learning must be considered, also.

In studies of the effect of sodium bromide and acetanilid on psychological function, tests were employed by us which were found to be useful for examining the general mental state of the test subjects. Although they are not adequate for all studies of drug action, they form the basis of an experimental procedure which can be applied to many psychopharmacological studies. The results of the study in which these tests were employed will be reported in another paper. The tests were chosen for ease and speed of administratoin, low susceptibility to practice, and adequate reliability and validity. They consisted of the following tasks: test of strength of grip of either hand with a dynamometer, the tapping test, a test of steadiness, a simple reaction time test, a choice reaction time test, and the cancellation test.

It required thirty minutes to administer the tests to each subject at one testing session, with rest periods where necessary. Care was taken that no two tests using the same set of muscles followed each

other, hence the test for strength of grip and the tapping tests were never given successively. With this exception, no particular sequence was followed in administering the items of the battery.

All test scores were available to all subjects so that an informal spirit of rivalry developed. This was felt to be desirable as it motivated the subjects to putting forth their best efforts, rather than going through the tests in a perfunctory manner. No attempt was made to encourage competition by rewards, however. Each subject received a small honorarium at the end of the experiment, but this was based upon faithful attendance and not upon test scores.

Strength of Grip.

The strength of grip of either hand, as measured by a dynamometer, has come to be considered an index of general bodily strength (7). The measure of strength of grip has a curious history. For centuries investigators have sought a series of measurements which would constitute a quantitative description of the fitness of the human body. The traditional emphasis has been upon anthropometrics, or the measurement of bodily growth and structure. This point of view was unproductive of any real understanding of the vigor of the human being and in years there has been an attempt to measure power instead of structure.

Much of this material has evolved in the field of physical education, led by Hitchcock (8) of Amherst in 1861. Sargent began to measure the strength of various muscle groups while he was a student at Yale in 1873 and at Harvard in 1880. The first psychological work along this line was that of Galton (9) undertaken in 1890. He sought to work out a battery of tests for measuring human efficiency in general and included a test of strength of grip. At about the same time Cattell and Farrand (10) worked on strength of grip as part of a program for analyzing individual differences. Soon interest spread in the test and Binet, Vaschide (11), and Claviere (12) in France, and Engelsperger and Ziegler (13) in Germany included strength of grip among their tests.

The psychologist is concerned with all phases of human behavior and he finds in the strength of grip test a simple and apparently adequate indication of the general physical well-being of an indi-

vidual. In addition it is indicative of the integrity of the central nervous system, as Hull (14) points out when he writes, "Consider a typical test of motor ability, such as strength of grip as measured by the hand dynamometer. The subject must have intact sense organs to receive the stimulus pattern which constitutes the examiner's instructions, an intact central nervous system to transmit the impulse to the particular muscles involved, and intact muscles to execute the response."

With the enthusiasm for mental testing which arose from the work of Binet in 1908, the influence of the first World War and the emphasis on intelligence testing, investigation of strength of grip declined until 1925. At this time Rogers (15) and other physical educators began work which indicates that strength of grip has marked significance as an indication of general fitness and today it constitutes one of the test items by which the Physical Fitness Index is established.

The validity of the strength of grip test has been established by decades of experimentation. It is positively correlated with physical condition and general bodily tone. Its validity is further vouched for by the fact that it does not correlate with tests of intelligence and other mental traits. Attempts to correlate it in this way have yielded such meager correlations as that found by Gates (16) who reported the correlation between strength of grip and Binet mental age was only .06, Woolley and Fischer (17) who found no correlation, and Paterson (18) who reported no relation between strength of grip and mental maturity.

Strength of grip seems to be a reliable measure of physical "tone" as it is not affected by fatigue unless the subject is forced to continue far beyond reasonable limits. In addition it seems to be reasonably free from the effect of practice. Once the subject has mastered the technique of using the dynamometer and knows what is expected of him, practice seems to have little influence on his scores. The factor of dextrality (hand preference or dominance) is taken care of by the routine procedure of establishing scores for either hand. The correlation of strength of grip with other tests of the battery used in this experiment is satisfyingly low, indicating that what is measured by the strength of grip test differs from that measured by the steadiness or tapping tests, for example. Re-tests on strength of grip show the

test to be exceedingly reliable. Griffiths (19) reported .95 coefficient of reliability of scores on successive days.

There are three types of dynamometer in use at the present time, the Smedley dynamometer which has a stirrup arrangement for a grip making it adjustable to various lengths of hand; an oval type perfected by Collins; and the push-and-pull type also by Collins. Neither of the latter two is adjustable.

The instructions to the subject consisted of a request to grip the hand dynamometer, to raise the instrument to the level of the head, then to bring it down quickly, meanwhile exerting maximal pressure. During the course of the experiment, in the strength of grip test three trials were taken for each hand, alternating from one to another, during each testing session. The score was considered to be the best of three trials for each hand.

The Tapping Test

The tapping test measures the speed of voluntary movement of a finger-arm involvement (20). Probably the earliest form of the tapping test was that devised by Binet. He asked his subjects to make dots with a pencil upon a piece of paper. They were to make as many dots as possible within the experimental period. Binet counted the dots produced and the score obtained could be compared with the individual's performance at another time, or it could be compared with the performance of other individuals, under the same conditions. There have been various adaptations of Binet's technique. Regardless of the method of tapping used, whether with a pencil, a stylus, a typewriter or telegraph key—the chief value of the test seems to be that it measures the motor speed of a limited group of muscles of the finger and arm. Because tapping involves a certain amount of attention and will (21) it has been widely used in studies of drugs such as caffeine (22), alcohol (23) and strychnine which affect these characteristics.

The tapping test can be administered in a brief period of time and it has been widely used since the turn of the century. As early as 1892 a tapping test was used by Bryan (24) based upon the earlier procedures of Von Kries, and others. From 1907 up to the first World War the tapping test was part of the battery used to study the college students who served as subjects for the annual psycho-

logical investigation at Columbia University and Barnard College (25). Since then the use of the tapping test has been most extensive and there is vast literature reporting it.

Although tapping is mainly a motor act and does not correlate with intelligence in adults (26), work on tapping by children indicates that a minimum amount of mental ability must be present and that tapping becomes a "real task" where there is mental impairment (27). For this reason, the tapping test is appropriately included among tests designed to measure alterations in the performance of subjects in whom the effect of a drug is being studied. F. L. Wells (28) has reported work with the tapping test, using it not only to measure fatigue but also as a diagnostic technique in mental disease. Bronner and Healy say of the tapping test that it is the only definitely psychophysical test they include in their manual.

The validity of the tapping test as a measure of speed of voluntary movement is substantiated by a large number of industrial researches with a view to evolving work aptitude tests. Link (29) used tapping in studying factory work ability and Kitson (30) related tapping to the movements and speed required in piano-playing and typewriting. The tapping test is also part of the batteries of Garfiel, Seashore, Cowdery, Paterson, and others. Because so many different modes of tapping have been reported, it is difficult to find evaluations of their reliability. Garrett and Schneck (20) report that the reliability of tapping is greatest after the limits of improvement have been reached. Gates (31) amplifies this report with the statement that practice effects are negligible once "subtle techniques" of tapping have been acquired by the subjects. In dismissing the effects of practice Ream states that " . . . Practice produces less variability in performance, improves technique, but does not better speed." This finding was the result of an experimental study in which six normal adults tapped daily for a twenty-day period. Book (33) also confirmed the observation that tapping scores are not improved by continued use of the eight different sets of muscles involved. He found in his work at Iowa State University in 1924 that novice typists, for example, did as well on the tapping tests as experienced typists at the same school. With a view to establishing the reliability of several tapping methods, Goodenough and Tinker (34) gave carefully controlled tapping tests to children and adults, and found high coefficients of reliability,

different according to the method used, but all in the neighborhood of .85 or better.

Forms of the Tapping Test

One of the oldest forms was Binet's, which has been described. A later version of Binet's method was used in the Columbia-Barnard ten year psychological study. Two types of the test were administered. One test consisted of one hundred squares, arranged ten vertically and ten horizontally in a column on a piece of paper. The subject was asked to put one dot in each. In the other method, one hundred dots, arranged similiarly, were used. The subjects were to "re-dot" or strike the printed dots on the paper. These tapping tests were known as the "Dotting tests" in the literature. Another method of tapping involves pricking a piece of paper with a sharp stylus, the number of perforations or markings on the paper made within the required time representing the subject's score on the test.

Since most versions of the paper tapping tests require the subject to tap on a mark or within the areas of squares ruled on paper, it is thought by some that the method involves the extra factor of hand-eye coordination in addition to the speed of voluntary movement of fingers and arm. Because of this objection, and because the labor of counting pencilled dots or punctures on pieces of paper is considerable, other methods for measuring tapping speed have been sought. A common method is the use of a telegraph key as part of an instrumental set-up of electric counter or kymograph. This has the advantage of giving an objectively recorded score of the taps made without introducing the errors which the experimenters might make in recording pencilled dots or stylus punctures.

Still another general method of studying tapping speed is the use of a special tapping board and a metal stylus which makes an electrical connection with a recorder. The latter two methods of tapping are considered to be more accurate measures of speed of movement than the others since they involve only the voluntary movement and do not require the precision of eye-hand coordination which comes into the paper tests.

In our experiment upon the effects of sodium bromide in relation to the tapping test, the apparatus consisted of a metal stylus and electric recording device. Alternate tapping plates four inches

square, mounted two inches apart on a board, were used. An electric counter, tapping stylus, dry-cell batteries, stop watch and knife-switch were used. The tapping plates, counter, stylus, and switch were connected in a series so that when the stylus came into contact with either plate a circuit was closed and the counter turned. The subject was instructed to hold the stylus in his right hand and at the signal "go" to tap the plates alternately as rapidly as possible. At the first tap the experimenter threw in the switch and simultaneously started the watch. At the end of thirty seconds the switch was opened and the counter read. This procedure was repeated for the left hand. The number of taps made by each hand was the subject's score. The work of Goodenough and Tinker indicates that this method of tapping has a reliability of .95 to .98 with adult subjects.

The Steadiness Test

Unlike the motor tests of strength of grip and tapping, the steadiness test attempts to measure differences in the individual's inhibitory ability rather than in performance. The primary task involved in all steadiness tests is that the fingers, arm, or occasionally the whole body be maintained as nearly motionless as possible. Any movement which is made under the conditions of a steadiness test is involuntary movement. In a sense it involves negative performance. The test employed in our study was of the type in which the involuntary tremor of hand and arm are measured.

The steadiness test was first employed by Hancock (35) about 1894 who used a "tremograph." The following year, a French investigator, Delabarre devised an instrument called a "digitalgraph" which measured involuntary movement in the fingers. Steadiness tests without the use of instruments have been in use for some time and make up part of a neurological examination by some physicians for tremors which are symptomatic of nervous system disease. However, steadiness tests using modern instruments have superseded other methods since 1910 as they offer an opportunity for more accurate scoring than the older techniques. A version of the steadiness test has been used industrially in a battery devised for motormen who were required to grip the handles of two vertical rods. Hand tremor was registered by an electric bell (36). This test has been a favorite experimental tool in the study of the effect of drugs. In 1923,

Hollingworth used the one-hole plate steadiness test in his investigation of alcohol because " . . . A familiar symptom of intoxication is gross tremor, trembling, or unsteadiness of hand." Hull (14) included the steadiness test in his battery for the study of the effect of tobacco smoking, and more recently Gilliland and Nelson (37) have used it to measure some of the effects of coffee or caffeine. Since sodium bromide is reputed to cause tremor as a symptom of intoxication (38), it was considered worthy of inclusion in our battery.

The steadiness test seems to measure a function or ability independent of other capacities, as its correlation with other motor skills is very low, according to Garfiel (26). Attempts to correlate steadiness scores with intelligence have likewise been unsuccessful, as shown by the study by Garfiel just mentioned, and a similar investigation by Sommerville (39).

There have been few attempts to study the reliability of the steadiness test with the exception of one careful investigation by Griffiths (19) which indicates a reliability of .71. He used the nine-hole Stoelting steadiness tester which is similar to the instrument used by us.

Physiological factors may affect the results of the steadiness test, according to Whipple and other authorities, but it is this very peculiarity which makes the test so suitable in the investigation of the effects of certain drugs.

The apparatus used in this battery consisted of the nine-hole Stoelting steadiness tester, a metallic needle or stylus, an electric counter, dry-cell batteries, a knife switch, and stop watch, mounted on a table. The tester, the stylus, the counter, the switch, and the batteries are connected in a series so that when the switch is closed and the stylus sticks to the side of a hole, the "touch" is recorded on the counter. The steadiness tester itself consists of a brass plate, set at a 45° angle, and pierced with a series of holes of graduated sizes, the largest commencing at the top row from the left, and the smaller five making up a second row of holes.

The subject was seated comfortably before the apparatus and instructed how to hold the stylus. At the experimenter's instruction he was directed to insert the tip of the needle in the larger hole and to try to hold it there fifteen seconds while endeavoring not to touch the sides. The counter recorded the number of touches made by the

subject within the trial period. Then the subject was tested on the other holes, from the larger to the smallest. Twenty seconds of rest between trials was allowed because the conditions of the test require the subject to take the test without support for the arm and hand. The score is computed by assigning a numerical value arbitrarily to each of the nine holes and to the value for each hole is added the total of contacts within the fifteen seconds allowed.

Some experimenters have found the apparatus described unsatisfactory for they claim that a very brief contact will not register on the electrical counter satisfactorily. To avoid this, some experimenters have followed the technique of recording on a kymograph as advocated by Whipple in his Manual, while the suggestion has also been made that the so-called telephone receiver type of recorder be used instead of a kymograph (40). The use of the kymograph seems unnecessarily laborious, and consequently the electric counter method was used and found completely satisfactory for a study of the effect of drugs.

Reaction Time

Because the reaction time may be studied in so many different sensory departments, the literature concerning it is extremely varied and confusing. The first observation of reaction time has become historic. In 1796, an unfortunate astronomer at the Royal Observatory at Greenwich was dismissed because his reaction time differed from that of his associates (41). In 1879 another astronomer named Bessel came across a report of this occurrence and began to investigate the problem of individual reaction time in a systematic way. His observations dealt with the reaction time in hand-eye coordination based upon the techniques of his day for astronomical recordings. Psychologists soon took over the problem of reaction time from the field of astronomy and began to study" . . . the time intervening between the application of a stimulus and the objective response of the subject (42)." There were studies of the speed of the subject's response to stimulation by light, sound, skin pressure and many other kinds of stimulation.

By 1865 Donders (43) had devised techniques for measuring reaction times which are quite similar to those in use today. He measured three kinds of reaction times. His first method required his

subject to lift the finger from an electric key as soon as he saw a flash of light. For some subjects, he required a response to a sound, similar to that in use today. Donders found that the simple reaction, as in response of movement to a stimulation of a flash of light, soon became automatic. In a second type of situation, which Donders called the discrimination-reaction test, the subject was told that two stimuli would be used, as for example, two differently colored lights. The subject was instructed to react to one of the two stimuli and to remain passive when the other was shown. A third type of test was devised which further complicated the situation. The subject was given two reaction keys and told there would be two stimuli. He was instructed to react by lifting the finger from the left-hand key when he saw one of the stimuli, and by lifting the finger from the right-hand key when he saw the other. This experiment was called the choice-reaction test. By 1885, Cattell and Dolley (44) were working on the problem of simple or complex reaction times and published a thorough article on the subject in 1894.

By 1900 techniques for studying reaction times were well established. Observers turned their attention to establishing reaction times for stimulation of different sensory organs. The reaction time variation within a single sense modality was studied. They also studied psychological conditions which affected the individual's reaction time. Woodrow (45) reported the importance of attention in altering reaction time, the presence of distractions having the effect of lengthening it. This effect was eliminated with practice, however. Fatigue was found to have little effect upon reaction time. In some cases it actually shortened the time interval.

Garrett and Schneck report that many studies of reaction time in relation to the effects of drugs have been made, and that these effects seem to be variable, caffeine shortening the reaction time; alcohol first shortening then lengthening the time, and morphine lengthening it.

In most of the investigations made before 1900, the reaction time was studied with a view to throwing light on the speed of conduction of the nerve impulse, and the role of intellect in discrimination and choice reactions. Since that time, the point of view of psychologists has changed. The trend has been, as Garrett defines it, to use the reaction time experiment "for measuring the difficulty of a task in an objective way, or as an index of the individual's efficiency under

different conditions." The reaction time test has been used in various forms in industry. Munsterberg (46) used it in his study of essential qualifications for motormen. The reaction time has been widely studied in its relation to competence at automobile driving, by industrial psychologists such as Moss and Allen (47) and Wechsler (48).

The feature of reaction time findings which makes the test especially applicable to studies of the effects of drugs is that the reaction time of an individual is relatively constant in a given task. In 1819 when Bessel investigated the reaction time in reference to astronomy, he made a number of observations simultaneously with Walbeck. The average difference was 1.041 seconds longer for Walbeck than for Bessel and there was "little variability about the average." Boring continues by quoting Bessel: "We ended the observations with the conviction that it would be impossible for either to observe differently, even by only a single tenth of a second." This fact, so long ago reported by Bessel, has been corroborated whenever reaction times have been studied. An individual's reaction time is consistent within very narrow limits for a specific stimulus-response situation. Psychological factors such as distractions can be minimized by preliminary practice, or better still, eliminated from the testing situation. Hence, the individual's reaction time is usually the same for a specific test situation unless the system is upset in some radical manner, as by the effects of drugs. The reaction time has already been studied in this connection. Macht, Isaacs, and Greenberg (49) have reported the alteration in reaction time due to the administration of opium alkaloids. Schilling (50) has studied the effects of acetanilid and caffeine. Meier (51) used the reaction-time test in studying the effect of sodium bromide upon epileptic patients. He found the reaction time reduced but the quality of the reaction impaired.

The validity of the reaction time is well established. No physiologist or psychologist would challenge the existence of this measure or deny that there is a reaction time peculiar to each individual for specific performances on specific tests. The reliability of the reaction time test has also been substantiated, with certain reservations. The finding that the individual's reaction time for a specific task tends to remain constant has been discussed above. This is substantially true but the measurement reaction time is so delicate, varying from tenths

to thousandths of a second, that it is not always identical with earlier scores on successive trials. It is usually safe to say that the reaction time of a given response in an individual will not vary more than one-tenth of a second, unless some unusual distraction or fluctuation of attention is permitted to enter the testing situation, or unless the individual's system has been subjected to the disturbing influence of fatigue or drugs.

Workers who have measured reaction time have become absorbed with an ever-increasing refinement of the units of time measurement. Such factors as the fluctuation in electric current in areas where alternating current is used have been taken into account (52). For the ordinary study such precautions are unnecessary since the usual reaction-time apparatus yields measures of the time-interval in tenths of seconds or less. When the measurement of reaction time test is made by a number of successive trials, and the results compared with retests of the same individuals even within a span of years, high reliability is demonstrated. Jones (53) reports an experiment at the University of California in which odd and even trials were correlated with Spearman-Brown correction yielding .83 to .90 for trials involving the same hand and .80 to .86 between the right and left hands of the same individual. He retested the same subjects after a year and found a reliability of .60 to .72 and then retested the third year after the original trials and found a correlation of .55 to .57 even over this long period. Johnson and Lauer (54) studied the first thirty trials for his subjects, comparing the first fifteen with the last fifteen, and found a .56 coefficient which yielded a reliability of .78 treated by the Spearman-Brown correction formula. Van Essen (55) describes the conventional manner of dealing with reaction times statistically. He writes, " . . . A large number of experiments have always been made in succession, and the average . . . taken, which was then further characterized with some index of deviation . . . (for) no one can escape the impression that the time values obtained in serial measurement normally group themselves around a central value."

The Marietta Reaction Board is the basis of the apparatus used in the reaction-time test for this battery. It is an upright board which shields the experimenter's activities from the subject. There is a telegraph key, chronoscope, buzzer, battery and light with red, green, and yellow screens, and knife switches on the experimenter's side.

On the subject's side are two telegraph keys. In the reaction time board is an aperture through which the subject is able to view an electric light with a red, green, or yellow screen. The board is so wired that when the experiment is about to begin, the experimenter strikes his telegraph key. This causes a buzzer to sound, warning the subject to prepare to observe and react to a visual stimulus. When the buzzer sounds, the chronoscope (a stopwatch measuring one-hundredth of a second and controlled by an electro-magnetic device) is automatically set. The experimenter then throws the switch which opens an electrical circuit. The experimenter then strikes his telegraph key again turning on the light stimulus and starting the chronoscope. When the subject strikes the appropriate key on his side, the watch stops, and the time interval is recorded.

The subject sits before two telegraph keys, resting his right forearm between them so that he may strike either key with his right hand. He is told that when he hears the sound of a buzzer, the experiment is to begin, and that he will be shown a colored light. As soon as he perceives this light, he is to depress the left-hand key. A series of ten trials is made for his reaction to a single light (yellow). The time between the sound of the buzzer and the illumination of the visual stimulus is varied, to prevent the subject from anticipating the show of light. This comprises the simple reaction-time test.

The choice reaction-time test is of the discriminatory type and is substantially like that already described. The subject is told that instead of the yellow light previously seen, he will be shown either a red light or a green light after the sound of the buzzer. If he observes a red light he is to strike the right-hand key, and if he observes a green light, he is to strike the left-hand key. The red and green lights are shown in random order to prevent the subject from anticipating which color to expect.

The chronoscope will record in units of hundredths of a second the length of time between the illumination of the light and the subject's reaction on a telegraph key. The subject's score is the average of ten trials for each of the tests, namely, the simple and the choice reaction tests.

Cancellation

Cancellation tests are of various types but the task of cancellation in general consists in asking the experimental subject to examine a

page of printed letters, digits, or words and to cross out with a pencil one or more particular items as they are found to recur. There is a definite time limit set upon the task and the scoring may be either the number of items cancelled within the time allowed, or the number of items correct less the number of errors, if the latter are made. Regardless of the kind of material used, the test is said to demand "... maximal attention ... for the best work, and ... any reduction of attention is reflected directly in the speed or accuracy of the work" (7).

Although motor skill is necessarily involved in the act of holding a pencil and crossing out the required items, cancellation tests are far more than tests of motor skills. Since Bourdon used the cancellation test in 1895 as a test for discrimination in adults, it has had extensive use. It has been variously described as a test of attention, of the rate of perception, of intelligence, or of association. Probably the task of cancellation involves all these functions or abilities. The subject who is confronted with a page of pied type in chaotic arrangement, and instructed to cancel out a certain letter, while working "against time," must have his wits about him. Recognition of the required letter necessitates discrimination of one letter as meaningful out of the printed jumble of the alphabet. The subject must coordinate visual discrimination with motor skill, while working at maximum speed. The cancellation test is very complex and while it shows no correlation with general intelligence it definitely involves the higher mental processes. For this reason it has been widely used in studies of the effects of drugs, particularly alcohol, and was included in our test battery because of our interest in finding whether or not certain drugs affect the individual performance on a test involving discriminatory mental function.

Cattell and Farrand (10) used the cancellation test in 1896 to study the "rate of perception of college students." Miss Sharp (56) made use of it in 1899. Her material consisted of a page of unspaced prose without capitals or punctuation. In 1907, two versions of the test were used in the Columbia-Barnard study, the so-called A-test and the a-test. Woodworth and Wells (57) have devised cancellation tests which have been in general use since 1911. There are also a number of special modifications of the cancellation test which have been devised for industrial use.

Gates (58) found a correlation of 0.30 between performance on the cancellation tests, and general reading ability, and also correlated cancellation with the Courtis Rate of Silent Reading test. Some experimenters believe that vision plays an important role in the cancellation test. For example, Hull (14) writes, "The A-test presents on the psychological level a measure of visual acuity and discrimination, combined on the physiological level with a measure of the rapidity of relatively simple movements of the hand." It seems evident that eyesight exerts a negative influence in cancellation performance where there is an impairment of vision, although the reverse does not hold true so that a very poor score should be compared with the subject's vision before conclusions are drawn from the cancellation test score."

The validity of the cancellation test seems to be adequate. It shows only slight correlation with general intelligence, as found by Vickery (59) in an experiment in which the A-test was given to eight college women. There was only a .25 correlation between cancellation and their scores on the Otis Self-Administering Test of Mental Ability. The reliability of the cancellation test is satisfactory. Most observers report some slight improvement attributable to practice, so an initial practice period should be given to eliminate this effect. Ordinary repetitions of the test show a reliability of .76 to .80 according to Paterson and Elliott (60), and Vickery reports a similar figure (.77) for reliability in the study by him already mentioned.

In Hull's (14) use of cancellation he took the precaution of preparing eight different forms of the A-test, each containing one hundred A-s, because otherwise, he says, the ". . . . Test would gradually have lost its discriminatory nature and have degenerated into something like a test of the rate of voluntary movement". He used each of his eight forms nine times within eighteen days. Other experimenters have avoided the hazard of repetition to familiarity in another way. Instead of using several versions of an A-test they have used the same test, but varied the stimulus letter or letters.

Woodworth and Wells (57) mention another minor factor, but one which might well affect the test results. The kind of pencil or crayon used for the actual cancellation is important. They write, "A pencil should be used for checking and while it were easy to appear hypercritical in this respect, even in so minor a detail as the

character of the pencil, approximate uniformity should be sought for . . .".

The cancellation test used by us consists of a sheet of paper covered with lines of lower case type. The lines of type are three-eighths of an inch apart, but the letters themselves are unspaced, and unpunctuated. There are twenty-six lines of ninety letters, comprising all twenty-six letters of the alphabet in random order. This permits the assignment of different symbols to the subject on different days, thus preventing his becoming familiar with the numbers and positions of given symbols on the page. The test is scored as the number of required letters cancelled in the given time, without considering errors, which are usually negligible. This is one of the conventional ways of scoring the cancellation test. The same type of firm pen was used by all subjects.

Summary

Methods for studying the effect of drugs on psychological function are described. The history of their use and the data relative to their validity and reliability are reviewed.

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